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The Clinical Utility of Pollen Counts

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Abstract

In this review, we describe how pollen counts are performed, the health effects caused by exposure to varying amounts of pollen, the clinical utility of reporting pollen counts to the public, and how that information can be used by patients who have allergies to improve their health. The public is very interested in pollen counts, particularly if the counts provide a forecast of expected pollen exposure for the next few days. Traditional pollen counts are labor-intensive; poorly distributed; and, since the counts are usually 1-day-old, do not provide forecasts that can be acted on. New methods that provide short- and long-term pollen forecasts can provide this information to allergic individuals so that they can respond to changing outdoor conditions. Studies of the relationship between artificial and natural exposure to pollen and development of symptoms have provided improved understanding into how much pollen it takes to cause symptoms. Thresholds for pollen counts that trigger symptoms vary by pollen type, sensitivity of the population, and interactions with other atmospheric exposures. Strategies to inform the public when the pollen count poses a health risk have been proposed along with computerized systems that provide personalized pollen alerts. The best performing public notification system was a "traffic light system" that reported pollen exposure as low, 0–30; intermediate, 31–50; or high, 51–150. This system outperformed other threshold systems used in Sweden and in Britain/Denmark. Continued improvements in pollen forecasting models combined with data provided by automated pollen counters and better public reporting should permit allergic individuals and urban planners to adapt effectively to changes in outdoor aeroallergen exposures.

Keywords Pollen · Ragweed · Allergic rhinitis

Introduction

Allergic rhinitis (AR) is estimated to affect approximately 10–30% of the world's population [1]. In 2012, 7.5% or 17.6 million adults [2] and 9% or 6.6 million children [3] were diagnosed with AR in the USA. It is associated with substantial reduction in the quality of life primarily due to impaired sleep which can lead to fatigue, irritability, and even absence from work and school [4••]. This is particularly problematic during peak pollen seasons. Direct costs include 11.1 million medical visits in addition to numerous days missed from work and school [5]. AR also is associated with indirect costs due to presentism which occurs when one is present at work or school but not performing well due to fatigue [4••].

Approximately 7.6% or 18.4 million adults and 8.4% or 6.2 million children in the USA are affected by asthma [6]. In 2014, there were 20 million ED visits for asthma and 3651 deaths due to asthma for a death rate of 1.1 per 100,000 population [7]. While medical management of AR and asthma is usually effective, the treatment itself has a burden including its cost, adverse effects, and the need to obtain and take medications [8]. Allergen immunotherapy, while highly effective, is also associated with expense and burden when done effectively.

Environmental control has been proposed as an approach to reduce the morbidity due to AR and asthma [9]. This primarily has been limited to control of the indoor environment because it can be more easily manipulated than outdoor exposures, though outdoor aeroallergens can penetrate indoors if windows and doors are open [10]. While exposure to outdoor pollen, fungi, air pollution, and particulates cannot easily be modified by an allergic individual, one can avoid going outdoors when exposure is likely to be high and to live in locations where exposure is relatively low. To do this, it is

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necessary to measure and predict exposure to outdoor aeroallergens and to understand how it affects an individual's health.

In this review, we will examine how pollen counts are obtained and whether there is clinical utility in reporting counts to the public. Since there is likely to be a dose-response between exposure to pollen and AR and asthma morbidity, we will review evidence for that relationship and how pollen information can best be used by the public to ameliorate symptoms. Finally, we will describe long-term changes in pollen exposure and how that information can be used for urban planning.

Pollen Counts

Pollen is the male gamete of seed plants that is involved in the transfer of haploid male genetic material from the anther of one flower to the stigma of another for sexual reproduction. Entomophilous plants use insects for transport of pollen, so they produce large sticky grains that rarely become airborne in sufficient numbers to trigger allergy symptoms. In contrast, anemophilous plants rely on wind to transfer pollen. This process is inherently inefficient making it necessary for copious amounts of pollen to be produced. These pollen grains cause allergic sensitization and, with continued exposure, lead to symptoms of allergic rhinitis, asthma, and allergic conjunctivitis.

Pollen grains range in size from 10 to 80 μM though most clinically relevant grains are in the 20 to 35 μM range. Anemophilous grains have surface structures that enhance their aerodynamic buoyancy so that they can remain airborne for long periods of time. A particle's terminal velocity is the rate of fall per unit of time (usually expressed as cm/s). This value determines how long a pollen grain can remain airborne in still air. There is an inverse relationship between the terminal velocity and the distance a pollen grain can travel. Early studies performed at the Brookhaven National Laboratory [11] demonstrated that pollen dispersal from a defined source in still air occurs rapidly and decreases to less than 10% recovery within 80 m. Given appropriate weather conditions, long-distance transport of pollen for hundreds of miles can occur [12].

The public generally is aware that exposure to pollen can trigger symptoms of AR and asthma. In one survey, 36 of 67 meteorologists across the USA reported pollen counts during their daily report [13]. Many people with allergic conditions pay attention to published pollen counts, and they may alter their behavior in response to them. Online sources such as Google Trends of search terms such as "hay fever," "allergy," and "pollen" demonstrate a seasonality that corresponds to pollen counts [14]. Pollen counts correlate with prescriptions for allergy medication [15]. Even tweets about allergies correlate with pollen counts [16]. To take advantage of counts, the public needs to be informed about their meaning and factors that can influence personal exposure [17].

In addition to public interest, pharmaceutical companies use pollen counts to time promotion of allergy medications and, in clinical trials, to measure health effects on sensitized patients as they experience natural pollen exposure. Pollen counts also are used by health agencies to issue alerts to the public when the counts are expected to be extremely high. The use of pollen counts for these purposes depends on an ability to accurately forecast them and to understand how the predicted counts are likely to affect populations at risk.

There are three approaches to doing pollen counts: (1) counts can be done daily and reported to the public for immediate use, (2) pollen forecasts based on historical data can be reported for short-term planning, and (3) long-term exposure can be modeled for use in urban land planning. While the first approach is well established, short-term forecasting models are now becoming accurate enough to be useful and long-term forecasting is still in a preliminary stage.

Daily Pollen Counts for Immediate Use

In the USA, pollen counts primarily are done in allergy clinics or hospitals as well as city or county public health departments where collectors typically are located on top of buildings [18]. Each station needs to have at least one and ideally two or more qualified counters who need to be trained and certified so that the quality of the counts is reliable. Since air samples are collected on the day before slides are processed, counts are necessarily 1-day-old even when reported daily.

While a variety of devices are available for collecting airborne particulates, pollen counts most commonly are done using volumetric samplers such as a Burkard sampler (Burkard Scientific Ltd., Uxbridge, UK) or Rotorod (QuintilesIMS, https://www.iqvia.com). Both of the devices provide similar results for pollen when compared side-by-side (about 80% efficiency of particle capture); however, the Burkard is a more efficient collector than the Rotorod for particles less than 10 μM in diameter, and as a result, spore counts tend to be underestimated with the Rotorod [19]. Wind speed also affects the efficiency of each of these devices with the Rotorod being most efficient at moderate wind speeds (> 10 miles/h) while the Burkard is more efficient at low wind speeds [20]. Sampling frequencies vary from continuously to once every 1 to 2 days. Each station needs to decide how frequently the counts will be determined throughout a 24-h period since each time division requires its own count. The height of the collector also can affect collection efficiency. In one study, more total pollen was collected at 1.5 M above the ground (25,204 grains) than at 35 M (16,218 grains) or 70 M (14,408 grains) [21]. Even so, many stations locate their

collector on roof tops so that they are unobstructed by neighboring buildings and for security reasons.

To provide daily counts, it is necessary for counting stations to be established in a distribution that is sufficiently dense that individuals with pollen allergy are likely to live near one. Ultimately, the results from a single station provides accurate information about the pollen count at a specific time and location. Since pollen exposure depends on local sources and weather conditions, a single pollen count may not adequately reflect average exposure for more than a short area surrounding the station [22•, 23]. In addition, pollen counts can display substantial diurnal and weather-related variation over short intervals of time [24–26] Short-term changes in weather can lead to dramatic changes in pollen exposure as demonstrated by epidemics of asthma when thunderstorms occur during pollen season [27•].

Currently, the process of doing a pollen count is so labor-intensive that the number of stations that can be maintained given limited funds is likely to be insufficient to adequately cover the population of allergic persons. These stations tend to be unevenly distributed, and in many cases, a single station is used to represent exposure for a community that covers a large geographical area. This is likely to be inadequate if there is a diversity of pollen sources.

Systems to accurately measure daily pollen exposure both for consumer and scientific purposes have been established in the USA and in Europe. The National Allergy Bureau (NAB, http://www.aaaai.org/nab) consists of 84 counting stations throughout the USA, one in Canada, and six in Argentina. The stations use volumetric samplers to collect airborne pollen which are then then enumerated microscopically. Counts provided by the NAB are derived from actual counts and do not rely on forecasting models. To provide data to the NAB, counters are required to become certified through a program that is administered by the American Academy of Allergy, Asthma & Immunology (AAAAI) Aerobiology Committee.

The NAB reports categories of pollen counts for tree, grass, and weed pollen based on data collected from counting stations in the USA. The categories represent quartiles for each type of pollen and range from low to very high [28]. It is important to understand that these categories do not indicate the effect that a given pollen count will have on health. They are merely an indication of how high an observed count is relative to historical counts.

The European Aeroallergen Network (EAN, https://www.Polleninfo.org) consists of 600 counting stations in 38 countries throughout Europe [29]. Though the pollen data are used primarily for scientific purposes, it is also available to the public. The network was initially hosted by the University of Vienna and is now hosted by the research group Aerobiology and Pollen information at the Medical University Vienna. A pollen information system also has been developed in Israel [30].

Pollen Forecasts for the Near Future

Daily pollen counts obtained by counting slides are necessarily 1-day-old. This does not permit planning of future outdoor activities which is as useful as a weather report that describes the previous day's weather. The public really wants near-term predictions of their likely future outdoor pollen exposure. For that reason, pollen forecasting has been attempted. One commercial company that provides 5-day pollen forecasts based on a proprietary historical model is pollen.com. This company is the source of counts for a variety of media outlets. Since the company does not have its own network of counters, it is not clear how accurate the forecasts are. The forecasts rely on historical pollen data combined with statistical models which are modified by weather forecasts to predict the likely pollen count for the next few days. Over time, these models can improve as additional real data is used to help it to "learn."

A system for forecasting also has been developed in Europe [31]. This starts by locating plants that produce pollens of interest. To do this, forecasters use a combination of satellite imagery and many local surveyors to document the density and type of plants that are present each year. The smaller the scale, the more accurate the model. Once the plants are located, it is necessary to determine when they will pollinate. This requires information regarding plant physiology and weather conditions throughout the continent. Surveyors monitor the maturity of plants to estimate when pollination is likely to occur. This process needs to be done each year because plant distribution changes over time influenced by introduction of new species, changes in land use, and climate change [32].

Once plants pollinate, it is necessary to determine how far the pollen will travel and in which direction. This depends on pollen buoyancy, light sensitivity, wind speed and direction, temperature, humidity, and rainfall [33]. Weather conditions also influence when the plants will stop producing pollen. Since the model is constantly being updated with new data, forecasts are likely to become more accurate over time [34].

In Austria, data from the European Aeroallergen Network is being used to forecast personalized pollen symptoms using a Patient Hay Fever Diary system [35]. The customizable forecasting model offers personalized warnings to users of a computerized system. The forecasts are provided to the public in a variety of formats including personalized apps for a smart phone. In a sample of 219 users, symptoms correlated with user numbers during peak pollen seasons each year. The largest user numbers and greatest symptoms were during the birch pollen season. This provided evidence that online consumption of pollen information corresponds with symptoms and with pollen counts in Austria [36•].

Long-Term Forecasts

Long-term forecasting depends on models that account for changes in land use which affects pollen sources and global climate change which affects the amount and potency of pollen produced as well as the types of plants that are present at a specified location [37]. Since pollen forecasts are less accurate the farther into the future they are, the goal is to predict long-term trends in pollen exposure which can help plan future land use and inform allergic individuals so they can decide where to live.

Health Effects of Pollen

Since pollen counts are commonly followed by individuals with allergic disorders, an important issue is whether there is a threshold or pollen concentration that is associated with development of allergic symptoms. This question can be divided into how the probability of developing symptoms changes with increasing concentrations of pollen exposure and whether symptom severity is correlated with the amount and duration of exposure to pollen. While it is assumed that exposure to pollen will trigger symptoms in an individual only if they are allergic to that pollen, the issue of cross-reactivity may complicate the matter. These questions can be addressed using two different approaches: chamber studies in which patients are exposed to varying amounts of pollen while symptoms are monitored, and natural exposure studies in which symptoms are monitored during pollen seasons.

One factor that may reduce the correlation between chamber pollen counts and symptoms is that airborne pollen allergens not associated with intact pollen grains can be detected and may trigger symptoms. This has been demonstrated both for grass pollen and for ragweed. Grass pollen can break open releasing starch particles that contain group V grass allergens (e.g., Lol p5, Phl p5) into the air when they become wet [38]. In another study, airborne Bet v 1 and Phl p5 was found to have a strong impact on symptoms of individuals with pollen allergy independent of birch and grass pollen counts [39]. A study of a ragweed allergen bioaerosol from pollen-free air found levels as high as 2.5 mg/M^3 during a time when the pollen count was 200 grains/M^3 [40]. This concentration persisted after rain washed pollen grains from the air suggesting that the bioaerosol may account for symptoms when pollen is not present. Therefore, pollen counts alone do not appear to give a complete indication of total allergen exposure. Pollen counts seem to represent a proxy for the actual allergen content which is difficult to measure on a routine basis.

Chamber Studies

One way to determine the clinical effect of pollen on allergic individuals is to expose them to known amounts of pollen in a controlled environment such as an exposure chamber while monitoring their symptoms [41]. In one study, ragweed-sensitized patients who underwent a ragweed challenge in a chamber developed symptoms over 90 to 120 min before reaching maximum [42]. In another chamber study of 206 grass-allergic, 191 ragweed-allergic, and 85 birch allergic subjects, nasal symptoms increased gradually reaching a plateau at 150 to 180 min for all three pollens [43••]. The severity of symptoms grew with increased pollen exposure until about 500 grains/M^3 when symptoms reach a maximum above which further exposure no longer had a greater effect [44].

Studies of Natural Exposure

Another approach is to study patients who experience natural outdoor exposure during pollen season. A list of selected studies is shown in Table 1. Such studies generally compare pollen counts with symptoms to identify a threshold above which symptoms occur and to identify the relationship between exposure and either number of patients who experience symptoms or symptom severity. Proposed counts estimated to elicit allergy symptoms are shown in Table 2.

In one study from Poland, investigators attempted to identify threshold pollen counts necessary to evoke allergic symptoms. The authors found a threshold for grass pollen of 20 grains/M^3 for 25% of AR patients to become symptomatic and 50 grains/M^3 for virtually all patients to have symptoms. In addition, 120 grains/M^3 was enough to trigger asthma symptoms in some individuals. For birch and alder, 24–30 grains/M^3 were sufficient to trigger symptoms [48].

In a prospective study of 430 children from 2000 to 2003 in the Northeast USA, asthma symptoms and medication use were compared to pollen counts for grass and weed pollens. The authors found that exposures of weed pollen as low as 6–9 grains/M^3 were sufficient to trigger asthma symptoms and as low as 2 grains/M^3 for grass pollen [49].

In a study of 98 children with AR most of whom also had asthma by Kiotseridis, a significant relationship was found between symptoms, medication use and pollen counts. Nasal scores increased linearly with pollen counts from 0 to 30 grains/M^3. After that, symptoms increased faster until counts reached 80 grains/M^3. Nasal symptoms did not increase with higher counts. A lag period of 3–5 days was noted between pollen exposure and appearance of symptoms [52]. It is possible that this was related to the increasing counts over time and intermittent natural exposure as well as to a priming effect.

In a study of 106 Poaceae-sensitized volunteers from 11 French towns, the relationship between symptoms and pollen

Table 1 Studies of natural pollen exposure and its effect on symptoms

Reference	No. of subjects	Parameters tested	Results	Description
Wu 1999 [45]	189 total 130 tree allergic 134 grass allergic Central Indiana	Tree pollen Grass pollen Symptom scores Medication scores	Tree with symptoms ($R = 0.73$, $P < 0.002$) Grass with symptoms (NS)	A prospective study revealed a symptom-score increase parallel to the rise of tree pollen counts beginning in mid-March and reaching a plateau in early May before the onset of grass season.
Viander 1978 [46]	38 patients 19 controls Immunotherapy study	Symptoms scores Birch pollen counts	90% of controls had mild symptoms when pollen counts exceeded 80 grains/M^3. 80% had symptoms below 30 grains/M^3 at the end of the season.	Evidence for priming due to seasonal exposure
Rapiejko 2007 [42]	640 pollen allergic subjects from Warsaw, Poland	Pollen counts Symptoms of AR, conjunctivitis, and asthma	Grass, alder, birch, and mugwort: first symptoms with 20 grains/M3. All had symptoms by 50 grains/M3 Worse symptoms at 65 and dyspnea at 120 grains	Threshold of 20 for symptoms after which the frequency and severity increase until 120
Jantunen 2012 [47]	64 birch allergic subjects in Finland	Pollen counts Symptoms Medications	$R = 0.34$ between counts and number with symptoms 29% at 10/M^3 62% 10–100 grains 83% > 100 grains	The percent of patients with symptoms increases with counts.
DellaValle 2012 [43••]	430 US children with grass and weed allergy	Pollen counts Asthma symptoms Medication use	6-9 grains weed pollen and 2 grains of grass pollen could trigger asthma symptoms.	Asthma can be triggered by low weed and grass pollen counts
Kiotseridis 2013 [44]	98 children with AR and asthma in Sweden	Grass pollen counts Symptoms Medication use	Nasal scores increased linearly from 0 to 30 grains. Increased faster from 30 to 80 grains No increase above 80	Nasal scores increase with counts starting with 1 grain. There is a 1–3-day lag between counts and symptoms.
Caillaud 2012 [48]	106 grass allergic patients from 11 French towns	Pollen counts Nasal symptoms	Symptoms increased linearly with counts < 10 grains/M^3. No further increase above 50 grains	Symptoms increased up to 80 grains at the end of the season suggesting a priming effect
Comtois 1988 [49]		Pollen counts Nasal symptoms	Symptoms in very sensitive patients: Grass, 4 to 12 grains/M^3; tree, 8 to 23 grains/M^3; and ragweed, 1 to 3 grains/M3. 10 to 50 grains/M^3 is required for most to become symptomatic.	Low counts can trigger symptoms in sensitive individuals. Higher counts trigger symptoms in a greater proportion.

counts was linear when counts were less than 10 grains/M^3 at the start of the season [50]. Above that, the increase in symptoms was more gradual, and above 50 grains/M^3, there was no further increase. By the end of the season, symptoms continued to increase up to 80 grains/M^3, suggesting a priming effect.

In a study by Comtois, 4 to 12 grains/M^3 of grass pollen, 8 to 23 grains/M^3 of tree pollen, and 1 to 3 grains/M^3 of ragweed pollen were found to elicit symptoms in allergic patients [53]. In Parietaria-sensitized patients, pollen has been reported to cause mild symptoms at 15 grains/M^3, moderate symptoms at 40 grains/M^3, and more severe symptoms at 80 grains/M^3 or more [54]. Florido found that concentrations of *Olea europaea* pollen elicited symptoms only when the counts reached 400 grains/ M^3 [55]. An Israeli study found that exposure to *Olea* pollen caused symptoms at concentrations of 2–4 grains/M^3, 4–5 for Artemisia, 3–5 for grasses, 10–20 for pecan, and 60–70 for cypress [56].

Once symptom thresholds are known, the next step is to inform the public about the meaning of pollen counts (Table 3). One study by Moriguchi compared symptoms collected from patient surveys with counts of Japanese cedar and cypress pollen collected at 10 sites in Kochi prefecture, to develop a three-level alert with the intention of improving quality of life for allergic persons living there [57].

In a study by Kiotseridis, thresholds from their study and two other studies were compared to determine which pollen thresholds would be most useful to alert the allergic population based on pollen counts. The best performing thresholds was a "traffic light system" with low, 0–30; intermediate, 31–50; and high, 51–150 [52]. This outperformed threshold systems used in Sweden and in Britain/Denmark [58, 59]. The

Table 2 Proposed thresholds for pollen exposure that triggers symptoms of AR

Proposed threshold (grains/M^3)	References
Tree pollen: 8–23 Grass pollen: 50–60	Comtois 1988 [49]
Ragweed: 1–3	
Olive: 400	Florido 1999 [50]
Grass: 50–60	Frankland 1990 [51]
Parietaria: 15 mild symptoms	Negrini 1992 [52]
40 moderate symptoms	
80 severe symptoms	
Grass: 20 (develop symptoms)	Rapiejko 2007 [42]
50 (100% have symptoms)	
160 (symptoms plateau)	
Birch: 10	Jantunen 2012 [47]
Ragweed: 6–9 for asthma Grass: 2 for asthma	DellaValle 2012 [43••]
Olive: 2–4 grains for olive	Waisel 2004 [53]
4–5 grains for Artemisia	
3–5 grains for grasses	
10–20 for pecan	
60–70 for cypress	

authors noted that the Swedish system has an unnecessary limit between "low" and "moderate" values at 10 grains/M^3, and that the British/Danish system includes a limit between "high" and "very high" that does not reflect a significant difference in symptom severity.

The French Aerobiology Network collected pollen counts and concomitant clinical symptoms for 15 years to define an index of "Allergenic Risk" of developing symptoms [60]. This index is used to forecast symptoms based on pollen counts on a scale from 0 (none) to 5 (very high). The index uses pollen counts, weather forecasts, and time of year to produce this index for different locations and for various taxa of pollen. The public can receive these alerts using an app developed by the network, which is available at http://www.pollens.fr/alerte-pollens.

Climate Change and Pollen Counts

The influence of climate change on the prevalence of allergic sensitization and disease is supported by observations that increased pollen exposure correlates with increased disease prevalence. Increased CO_2 concentrations have been shown to increase the number of pollen grains produced by ragweed plants [61], and each pollen grain has a greater concentration of Amb a1, the major ragweed allergen [62]. In addition to producing more pollen with enhanced potency, the pollination season has been shown to be prolonged [63], an effect that is particularly pronounced at higher latitudes most likely due to warmer weather during early fall [64].

In addition to increased pollen production and enhanced potency of pollen grains, fungi that grow on CO_2-enhanced leaves produce more fungal allergens [65]. A review of the literature described studies documenting CO_2-driven increased plant size, greater pollen production, and more allergenic pollen for a variety of pollen species from Texas to Canada [66].

Table 3 Alert levels used to inform the public about pollen counts

Source	Pollen	Proposed levels	Reference
French Aerobiology Network	Multiple pollens	0 (none) to 5 (very high)	Thibaudon 2003 [57]
	Japanese cedar and cypress	0 (safe) 1–30 (attention) > 31 (precaution)	Moriguchi 2001 [54]
Traffic lights	Grass pollen	Low, 0–30 Intermediate, 31–50 High, 51–150	Kiotseridis 2013 [44]
Swedish Public Warning System	Grass pollen	Low, 0–10 Moderate, 11–30 High, 31–100 Very high, > 100	Stewart 2008 [55]
Britain/Denmark	Grass pollen	Low, 1–30 Moderate, 31–50 High, 51–150 Very high, > 150	Davies 1973 [56]

In a study of Europeans sensitized to ragweed pollen (recently introduced into the continent), as pollen counts have increased, sensitization rates also have increased reaching a plateau at around 40% of individuals exposed to extremely high counts. As a result of this increased pollen exposure, it has been estimated that the prevalence of ragweed sensitization could double from 33 to 77 million by mid-century [67••]. A similar correlation was found in Slovakia for a variety of tree and weed pollens. In addition to a correlation with pollen counts, sensitization rates also increased with lengthening pollen seasons that have occurred in response to climate change [68].

The influence of climate change on the prevalence of allergic sensitization and disease, while largely circumstantial, is supported by observations that increased pollen exposure correlated with increased prevalence of asthma and AR [69–71]. On Mauna Loa observatory in Hawaii, CO_2 levels have been increasing steadily from just under 320 ppm in 1960 to just under 410 ppm by 2015 [72]. Due to the greenhouse effect, this increase appears to be the primary driving force for global temperature increases that have occurred during this time. While this issue has been politicized in the United States, there is little doubt in the scientific community that the effect is real. Rises in CO_2 are more pronounced in cities than in parks or farms [45].

Air pollution also has been shown to contribute to symptoms of AR and asthma independent of exposure to bioparticulates [46]. There is also evidence that increased concentrations of pollutants such as ozone (O_3), nitric oxides (NOx), sulfur dioxide (SO_2), respirable particulate (PM10), and volatile organic chemicals (VOCs) correlate with increased prevalence of allergic diseases and can increase airway responses to allergens in atopic patients [47].

The Future of Pollen Counts

Because traditional methods for doing pollen counts provide day-old results and are labor-intensive, newer technologies are being developed to provide automated, real-time counts using computerized image recognition. One devise is Pollen Sense™ (http://pollensense.com) which provides real-time automated pollen imaging and can count different species of pollen. The device can also register other organic and inorganic particles, down to less than 5 μm. If automatic devices become available, it may be possible to create a large network of regularly spaced stations to more accurately predict pollen exposure.

Short-term forecasts can alert patients when to start medications and to schedule vacations during local pollen season. Forecasts can also permit park workers to time when to mow lawns prior to release of grass pollen. In addition, public activities can be planned to avoid peak-pollen days and hours.

Models for long-term forecasts can predict the likely change in ragweed distribution due to climate change and its effect on pollen counts as well as sensitization rates, which are estimated to double in Europe from 33 to 77 million by mid-century [67••]. Long-term mitigation using forecasts can be used for city planning of types and locations for ornamental plants, species used in parks, recreation zones, and their location. Agriculture planning could include locating fields growing allergenic species either at a distance or downwind from cities. In some cases, it might also be feasible to implement eradication measures against invasive species such as ragweed in Europe.

Conclusions

Pollen counts are followed by the public because knowledge of outdoor aeroallergen exposure can help allergic individuals to better plan outdoor activities to limit their exposure. To be most effective, the counts need to be accurate, timely, and they should be measured near where allergic individuals live. Automated pollen counters may help this to happen. Short-term forecasts can help patients to plan their daily activities while long-term forecasts can help them plan vacations and where to live. Urban planners also can use the information when designing cities and surrounding land use. While forecasts are complicated by many factors including air pollution, climate change, and encroachment of invasive plants, the technology both to model and distribute the information to the public is improving.

Key Points

1. The public is very interested in pollen counts, particularly if they can forecast exposures over the next few days
2. Thresholds for pollen counts that trigger symptoms vary by pollen type, sensitivity of the population and interactions with other atmospheric exposures
3. Long-term forecasts of pollen counts may provide information that can help individuals plan vacations and where to live and urban planners how to better manage the land to minimize unwanted exposure to city inhabitants.
4. Improvements in a variety of technologies should permit more accurate short- and long-term pollen forecasts.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Ethical Approval and Informed Consent This was a review article and not a study involving human subjects, so IRB approval was not required.

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•• Of major importance

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